PROBABILITY: THE LANGUAGE OF RISK ASSESSMENT

3.15 Introduction

How and why do scientists "quantify" relationships among risks?

One step in protecting public health and improving public safety is determining the risks involved with activities and technologies. To be able to discuss and compare risks, a common language is needed. For this reason, scientists and decision makers quantify relationships among risks by developing number values called mathematical probabilities.

3.16 Everyday Use of Probability

What is probability?

How "likely" something is to occur is known as "probability." Most people, including you, use probability in their everyday lives. For example, a local weather forecaster (or meteorologist) may forecast rain. The forecast is made by comparing scientific knowledge gained from observing similar conditions in the past to the existing weather conditions. Through this comparison, the meteorologist can tell us what percent chance of rain there is. Then you can decide whether or not to carry an umbrella. If you are cautious, you may decide to carry an umbrella if there is only a 30 percent chance of rain. Or you may wait until a 70 percent of rain is forecast.

What was the weather forecast?

How are percentages related to probability?

Percentages and probabilities are related but not the same. Percentages are a mathematical statement of how many times out of 100 something happens. Probabilities refer to just one happening. For example, a 30 percent chance of rain at a particular weather station means that given these same weather conditions for 100 different days, it is expected to rain 30 of those days. The probability of rain for any one of those days is 30 divided by 100, which equals 30/100 or .30.

$$30 \div 100 = .30$$

Repeated Observations and Experiments

What is the mathematical formula for determining probability?

Most of the probabilities we use in every day life are determined from simply observing what happens every time certain conditions arise or from repeating an experiment many times. The number of times that a specific outcome occurs, divided by the total number of times the experiment is repeated, is the probability that the specific outcome will occur. This is useful for making predictions about what will happen in the future.

$$\frac{\text{Number of times outcome occurs}}{\text{Total number of repetitions}} = \text{Probability}$$

Let's use an example similar to the one above. The same weather conditions were observed and recorded for 100 days during the past 2 years. Forty of those 100 days were sunny and warm. This Tuesday, we expect the weather conditions to be very similar to those 100 days observed in the past 2 years. What is the probability that this Tuesday will be sunny and warm?

$$\frac{\text{40 sunny days}}{\text{100 repetitions}} = \frac{40}{100} = 0.40$$

Common Sense

What is a .50 probability?

Some probabilities are common sense. For example, we know that when we flip a coin, there are only two possible outcomes —heads or tails. So there is a 50 percent chance (a 0.50 probability) that the coin will land heads up. There is also a 50 percent (0.50 probability) chance that it will land tails up. If we want to know how many times a coin is expected to land heads up on a certain number of flips, we don't have to actually flip the coin. We can simply multiply the probability of heads by the number of times we would flip the coin.

10 Flips?

10 x 0.50 = 5 Heads

2,000 Flips?

2,000 x 0.50 = 1,000 Heads

Heads or tails?

Random events like the coin flip cannot be predicted with certainty. Every time the coin is flipped, there is a 0.50 probability of heads and a 0.50 probability of tails. If a lot of flips in a row land heads up, the probability that the next flip will be tails is still 0.50. But the more total times the coin is flipped, the more likely it is that heads will occur 50 percent of the time and tails 50 percent.

Can outcome always be predicted with certainty?

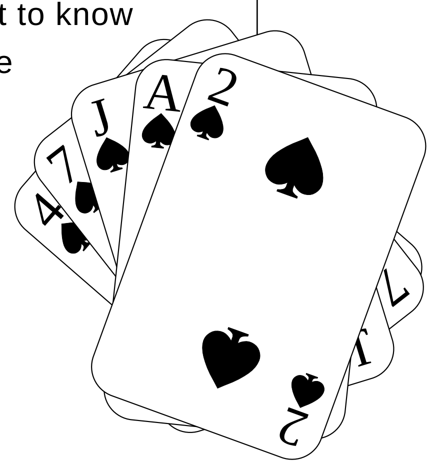
3.17 Figuring Probability

The same principles apply to other events. Suppose there are a certain number of possible outcomes to an event, and each event has an equal chance of happening. Then the probability of each outcome is 1 divided by the number of possible outcomes.

What is the probability of drawing the ace of spades from an ordinary deck of cards?

For example, the probability of drawing the ace of spades from an ordinary deck of cards is 1/52. Now, if we want to know the probability of drawing any ace on one draw, we add the probabilities of getting a particular ace together. There are four aces out of the 52 cards, or one ace per suit. The probability of drawing any of the four aces on a single draw is 1/13.

$$\frac{1}{52} + \frac{1}{52} + \frac{1}{52} + \frac{1}{52} = \frac{4}{52} = \frac{1}{13}$$



How many aces are there in a deck of cards?

For example, you may want to know the probability of drawing the ace of spades from an ordinary deck of cards. There is only 1 ace of spades in the deck of 52 total cards. That would be:

$$\frac{\text{1 favorable outcome}}{\text{52 possible outcomes}} = \frac{1}{52} = 0.02$$

If you want to know the probability of drawing any ace, you can apply the same formula. There are 4 aces out of 52 cards (1 ace for each suit). This means there are 4 favorable outcomes out of 52 possible outcomes.

$$\frac{4}{52} = \frac{1}{13} = 0.08$$

You could also add together the probabilities of getting a particular ace.

$$\frac{1}{52} + \frac{1}{52} + \frac{1}{52} + \frac{1}{52} = \frac{4}{52} = \frac{1}{13} = 0.08$$

How do we determine the probability of independent events occurring together?

Suppose you are playing cards and you want to know the probability of drawing a particular hand — 5 cards of the same suit (a flush). Think of each draw as a separate event. Remember also that the number of favorable and possible outcomes will be reduced by one after each draw.

First draw: There are 13 favorable cards out of 52 total cards

$$\frac{13}{52}$$

Second draw: There are now only 12 favorable draws out of 51 cards $\frac{12}{51}$

Third draw: There are 11 favorable cards remaining out of

50 cards $\frac{11}{50}$

Fourth draw: There are 10 favorable cards remaining out of

49 cards $\frac{10}{49}$

Fifth draw: There are 9 favorable cards remaining out of

48 cards $\frac{9}{48}$

To determine the probability of independent events happening together, you must multiply the individual probabilities together. So for drawing a flush:

$$\frac{13}{52} \times \frac{12}{51} \times \frac{11}{50} \times \frac{10}{49} \times \frac{9}{48} = \frac{154{,}440}{311{,}875{,}200}$$

$$= 0.000495$$

$$= \frac{495}{1{,}000{,}000} \text{ or 495 in 1 million}$$

Multiply by 4 to account for all 4 suits:

$$\begin{array}{r} 0.000495 \\ \times \quad\quad 4 \\ \hline 0.001980 \end{array} \quad \text{or} \quad \frac{198}{100{,}000}$$

The chance of drawing a flush in any suit in 5 draws is 198 in 100,000. If you drew five cards 100,000 times, you would be likely to draw a flush 198 times.

3.18 Health and Safety Risks

Why are probabilities involving health and safety risks to humans hard to determine?

Other probabilities, including those for health and safety risks to humans, are harder to determine. A lot of information may be needed to make a prediction. Or testing the whole system may not be possible. However, once the basic probability for each possible outcome is known, the same rules apply and can be used to make reasonable predictions.

For instance, suppose that, by law, a company cannot distribute a machine until certain safety standards are met. The company knows the machine will not operate safely if two particular parts break down at the same time. This situation could exist if one part is a backup for the other. The company couldn't wait until after the machines were distributed to see how many times out of 100 the two parts would break down at the same time.

However, the company could conduct tests on each part to find the probability for each part breaking down. Then these probabilities could be multiplied to determine the probability of both parts failing at the same time.

For example, suppose tests determined that the probability of part A breaking down was 0.05 and the probability of part B breaking down was 0.02. Then the probability of both parts breaking down is 0.05×0.02. This equals 0.001 or 1/1,000 (one in a thousand). If that level of risk is acceptable to the company and meets industry regulations, then the company could distribute the machine.

One in a Million

When is a technology considered "safe"?

In the case of human health risks, a rule used in some cases by regulators is that a technology (new chemical, new industrial plant, etc.) is "safe" if it does not increase the health risk of the population by more than 1 chance in 1 million. This is about the same chance each of us has of being struck by lightning or a meteorite.

Nuclear waste disposal is governed by a principle of minimizing risk to the public and environment to "as low as reasonably achievable" — ALARA. Many steps are taken in nuclear waste disposal, as with other nuclear power activities, to reduce public risk from radiation to at most one in a million.

Limitations

One problem is that to know if risk increases, we have to know what the risk is before the "new risk" is introduced. Also, often increased risk is based on laboratory experiments using large numbers of animals. Large numbers of subjects are helpful, but the biological differences between the test population (often rats or mice) and humans introduce more uncertainties.

What is the difficulty with this rule?

Probabilities do give us a way to determine a level of risk that is at least to some degree not subjective. But it is important to understand that personal judgment is still involved. For example, choosing what to consider in an experiment requires some judgment.

3.19 Consequences and Values

Determining the acceptability of risk involves both the consequence of the action in question and values. If you decide not to carry an umbrella, the consequence may be that you get wet if it rains. How much risk you are willing to accept depends on whether you mind getting wet.

How do you determine the acceptability of risk?

Human Health Risks

Of course, in situations involving technologies, decision making is much more complicated. Difficulties can arise in determining an acceptable level of risk when the consequences could involve risk to human health or life. Still, since risk cannot be eliminated but may be reduced, it makes sense to quantify the risk in complex technologies. By identifying the risks of each event in the technology, events where risk can be reduced can be

Why are situations involving technologies complicated?

How do you quantify risk in complex technologies?

identified. This may reduce the overall risk of the technology. In some cases, the costs of reducing risk to very low levels may be very expensive. A value judgment is then required to determine the level of risk considered acceptable.

Making Societal Decisions

Are there limitations to the usefulness of probability as a tool for discussing risk? Why?

Using probability as a tool for discussing risk is useful, but it is important to recognize that there are limitations in using probability for making decisions about the acceptability of risk. For example, most societal issues in which risk is a factor are complex. A significant problem may be discounted or underestimated. Also, many probabilities are estimated because it is not possible to perform controlled experiments to measure them. Furthermore, human behavior and human error are even less predictable than physical or biological events.

Other Aspects of Risk

Is probability the only aspect of risk?

Probability is only one aspect of risk. Societal risk decisions also involve consequences and values. What is the consequence of a failure — loss of money, illness, death? How large are the consequences? Do the risks and benefits fall on different people? Do the risks fall on the decision-makers or on others? How are decisions made? What are the alternatives?